The *Picturephone*® System:

Central Office Switching

By P. N. BURGESS and J. E. STICKEL

(Manuscript received September 30, 1970)

Central office switching of Picturephone® *calls required the design of an automated network capable of switching large numbers of wideband signals on an analog basis. We describe in this paper the development of a switching plan that allows for the interconnection of many customers to many trunks and at the same time stays within acceptable transmission limits. We also give an explanation of the transmission constraints on the physical design of the central office network.*

I. INTRODUCTION

Although devices have been developed to switch megahertz bandwidth signals, they have been limited to a small number of inputs and outputs. Also, the logical controls for these devices have been relatively simple. The development described in this article is the first automated, large-scale switching system designed to switch large numbers of wideband signals on an analog basis. We discuss the network and controls added to the No. 5 crossbar switching system that enable an existing switching system to process calls from *Picturephone* stations as well as telephones.

1.1 *Design Philosophy*

Picturephone service is intended to be an extension of basic telephone service rather than a separate communication package. This fact has important implications in all of the Bell System, particularly in the design of switching systems. As such, the wideband switching system developed for *Picturephone* service utilizes the existing telephone plant as much as possible. Clearly this design method is reasonable from an economic standpoint since a large number of existing telephone switching functions—registration of dial digits, charging, call supervision, signaling—are also needed for *Picturephone* switching. This philosophy also implies a natural extension of the standard numbering plan; therefore, a *Picturephone* customer can receive both *Picturephone* and telephone calls on the same number. The only difference between dialing a *Picturephone* call and a telephone call is that the dialed digits for a *Picturephone* call will be prefixed with the 12th *Touch-Tone*® button designated (#).[1]

The No. 5 crossbar system was chosen the switching machine to provide initial service for *Picturephone* customers. That system is widely available throughout most of the major metropolitan areas in the United States. It is organized on a common control basis and, because of its inherent flexibility, can add new services such as *Picturephone* calling. Future developments will provide this capability in electronic switching systems.

1.2 *Application*

The system to be described is capable of serving as a local switching system by handling *Picturephone* calls to and from (*i*) individual lines, (*ii*) centrex lines, (*iii*) PBX switching systems modified for *Picturephone* service, and (*iv*) Bell System operators. The centrex lines, either terminated directly in the central office (centrex CO) or on an associated PBX (centrex CU), will be able to receive direct-in-dialed (DID) calls, to originate automatically-identified-outward-dialed (AIOD) calls, and to key four- or five-digit intercom calls. Transfer features for centrex CO customers will be provided in a later development.

In addition, the system will serve as a toll and tandem machine by switching calls between *Picturephone* interoffice trunks on an analog basis.

II. SWITCHING PLAN FOR NO. 5 CROSSBAR

2.1 *Central Office Switching Network*

The switching plan is influenced by the electrical interface with the *Picturephone* set. This interface is presented over three pairs of wires: one for the bi-directional audio signals, and the other two for the video transmit and receive signals. The audio pair is switched by the existing No. 5 crossbar two-wire network, while the video pairs are switched by a new four-wire network, essentially in parallel with the audio network (see Fig. 1). For control purposes, this new switching network, called the wideband link (WBL), is associated with the two-wire network in a definite manner. On the line side of the

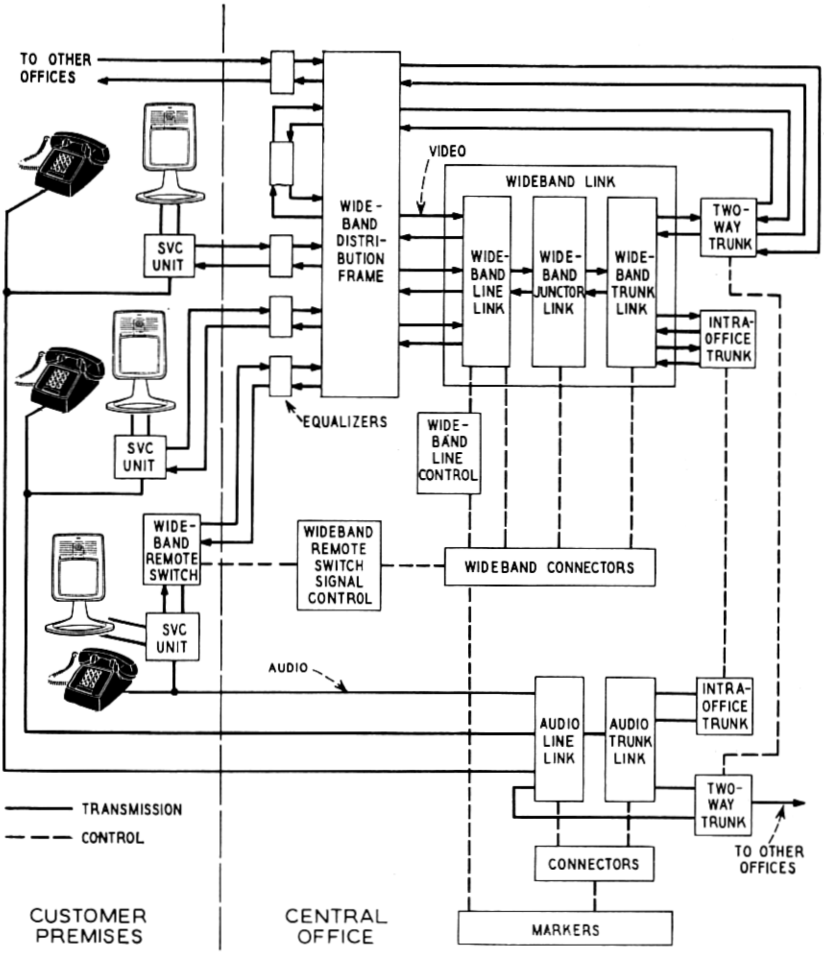

Fig. 1—Switching plan. (WBRS = wideband remote switch; WBRSSC = wideband remote switch signal control.)

network, the *Picturephone* station's audio appearance on the two-wire network is associated directly on a one-for-one basis with the video appearance on the WBL. Whenever the *Picturephone* station is involved in a *Picturephone* call, one path is switched through the audio network to the audio appearance, and another is switched through the WBL to the associated video appearance. If a *Picturephone* station is involved in a telephone call, only the audio portion is switched through the office.

On the trunk side of the network, the same association principle holds such that every audio trunk with an appearance on the two-wire network has an associated video trunk with an appearance on the WBL. Interoffice *Picturephone* calls are switched via video trunks and their two-wire counterpart. The control is arranged so that these audio trunks are never used for telephone calls.

With this switching plan, the probability of a *Picturephone* call being blocked is greater than or equal to that of a telephone call since a *Picturephone* call is routed through two switching networks rather than one. Although the two networks are not stochastically independent, the dependence is small because the switched channels are selected independently. In particular, if P_A and P_V are the probabilities of a particular input being blocked in the audio and video network, respectively, and P_P is the probability that a *Picturephone* call is blocked through this office, then

$$P_P = 1 - (1 - P_A)(1 - P_V),$$

$$= 1 - (1 - P_A - P_V + P_A P_V),$$

$$= P_A + P_V(1 - P_A).$$

Since

$$P_A \ll 1, P_P \approx P_A + P_V .$$

The probability of a *Picturephone* call being blocked should not be significantly above the blocking probability of a telephone call. Hence, P_V should be significantly smaller than P_A, and the WBL should be nearly nonblocking.

The above requirements have been satisfied by using a three-stage network which has nearly all the expected blocking in the first stage. Since the second and third stages approximate a Clos nonblocking network[2], the blocking is nearly zero through these stages. By allowing concentration in the first stage of up to 8:1, the telephone company has the flexibility of controlling the blocking in the network by line reassignment. The network can be provided with a minimum of 100 trunk terminations and is expandable, in 100-trunk termination increments, to the 400-termination size. Market studies have indicated that, for the early years of service, a network with 400 trunk terminals is adequate. For each of the four sizes, a 4:1 or 8:1 line concentration ratio is available. The network topology is shown in Fig. 2, and described below where $N = 1, 2, 3,$ or 4.

The first stage consists of $10N$ wideband line links, each line link having ten outputs and 40 or 80 inputs for a maximum of 3200 lines.

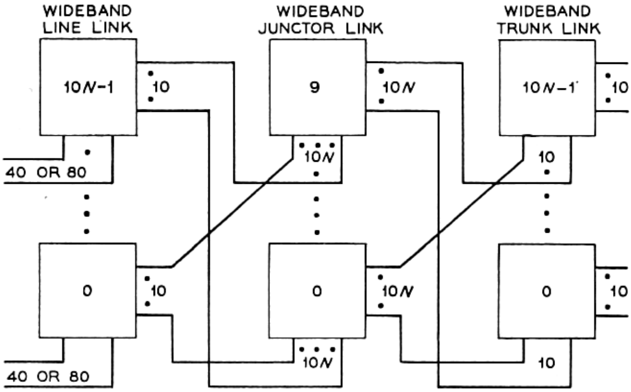

Fig. 2—Wideband network topology.

The second stage, the wideband junctor link stage, consists of 10 junctor switch groups, each group having 10N inputs and 10N outputs. The third stage, the wideband trunk link stage, consists of 10N groups, each having ten inputs and ten outputs. The packaging of this equipment and its impact on the central office floor plan as it affects the transmission characteristics is explained in Section III.

The ten outputs (horizontals) of a line link are spread over the ten junctor switch groups. The outputs (horizontals) from a junctor switch group are spread uniformly over the wideband trunk groups. This network configuration provides ten paths between any input and any output.

2.2 *Remote Switching Network*

A prime candidate for early *Picturephone* service is the centrex business customer. While he will eventually be making many calls to other customers as the national *Picturephone* network grows, he will initially be making a large percentage of calls within the community of interest on his own company premises. If the WBL were the only switching network provided in the switching plan, every call between two stations within the customer group (i.e., intercom calls) would involve two sets of transmission facilities between the customer and the central office. By providing a switching network at the customer's premises, the wideband portion of intercom calls can be switched entirely at the customer's location, thus reducing the transmission facilities needed by the customer for this type of call. The wideband remote switch (WBRS) was designed to meet this need. It is arranged to switch just the video signals, and most of the control* of the WBRS is in the central office. The audio for each station is still switched at the central office implying that no modifications are necessary for the existing audio facilities already provided by centrex CO arrangements. As a consequence of providing the WBRS near the customers, a reduced number of transmission links are provided between the central office and the output of the WBRS. Therefore, the WBRS can also function as a switching concentrator for *Picturephone* centrex customers.

The WBRS is arranged as a single stage crossbar network with 80 inputs and 20 outputs. The inputs accept the video transmit and receive pairs from the *Picturephone* station and the outputs either connect directly to the WBL so as to provide video links to the rest of the *Picturephone* network or connect to intra-remote switch trunks. These trunks complete the switched video connection on *Picturephone* intercom calls.

III. TRANSMISSION CONSTRAINTS ON PHYSICAL DESIGN

The problems of crosstalk, impulse noise, insertion loss, and echoes in a large scale 1-MHz bandwidth switching network presented an unusual challenge to the switching system designers. In addition to providing a satisfactory transmission path, this network had to be practical from a manufacturing, installation and maintenance standpoint. This section is devoted to a discussion of how these constraints influenced the resulting physical configuration of the network.

Figure 3 shows the wideband network in terms of the actual apparatus utilized in switching the *Picturephone* call. Each line link consists of two or four 20-vertical, ten-level, six-wire crossbar switches, each $34\frac{5}{8}$ in. $\times$ $9\frac{1}{2}$ in. The junctor switch groups each have up to eight crossbar switches, like those in the line link, and each trunk switch group has one ten-vertical, ten-level, six-wire crossbar switch, $20\frac{1}{2}$ in. $\times$ $9\frac{1}{2}$ in. Regardless of the method of equipment packaging, the distance through the wideband network is an appreciable part of the *Picturephone* signal's wavelength and the transmission characteristics of the switching network must be considered. To control these transmission characteristics, the wideband network was designed within the constraints imposed by an overall transmission *level plan* for analog facilities.

* "Control" is used in the broad sense: it includes registration of dialed digits and translation of information as well as electrical control of the network.

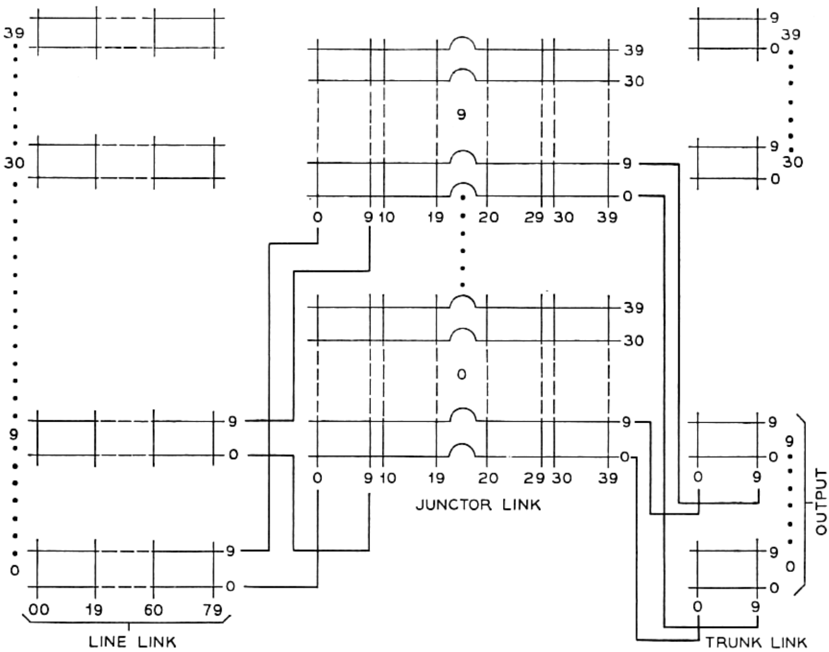

Fig. 3—No. 5 crossbar wideband switching link network.

3.1 *Level Plan*

The overall level plan states that the output of any cable equalizer must be at the same transmission level. This reference point, Zero *Picturephone* Transmission Level Point (0 PTLP) is defined as the output of the central office loop equalizer in the direction of transmission from the station set to the central office. Beginning at the station set equalizer, shown in the overall level plan, Fig. 4, each subsequent equalizer compensates for its preceding transmission path and its output is adjusted to be at 0 PTLP. As long as the signal degradation in this preceding path is reasonably constant and predictable, the equalizers need to have only fixed gain and phase characteristics (fixed equalizer).

The *Picturephone* switching network level plan for No. 5 crossbar, shown in Fig. 5, must satisfy the same transmission requirements as the overall level plan. This plan was particularly difficult to implement within the central office since any of the maximum 3200 *Picturephone* lines could connect to any of the 400 wideband trunks. This meant that the variation in transmission degradation among the paths through the wideband network had to be within the tolerance allowed in 0 PTLP. To accomplish this, additional transmission constraints were imposed internal to the central office. These constraints still allow fixed equalizers (rather than dynamic equalizers) to be utilized. In addition, traffic balancing of both *Picturephone* lines and trunks is required. The level plan and traffic balancing requirements are satisfied by the use of a wideband distributing frame (WBDF) located a fixed electrical distance between the cable equalizers and the switching equipment. To allow traffic reassignment without equalizer readjustment, the input ($S1$) and output ($S3$) levels at the WBDF are fixed.

3.1.1 *Transmission Cable Length Restrictions on Wideband Network*

Starting at any of the cable equalizers shown in Fig. 5, the effective distance to the WBDF is fixed so that the transmission loss is constant and equal to the loss of 350 feet of cable. This distance, chosen because of the anticipated size of cable equalizers and expected central office space availability, represents the longest cable run from an equalizer to the WBDF. For equalizers closer to the WBDF, the 350-foot path may be a combination of cable buildouts (BO) and actual cable. The level of $S1$ is therefore equal to 0 PTLP minus the transmission loss of 350 feet of cable. The distance from the WBDF through the switching network and back to the WBDF is 320 feet with an allowable variation of ± 50 feet. This nominal distance and variation was chosen after a study of trade-offs was made, considering the following:

(*i*) Cost and practical limits of gain and phase compensation in the fixed equalizers.
(*ii*) Central office space availability for the wideband network.
(*iii*) Minimum cable distances possible through a network that has a maximum of 280 crossbar switches.

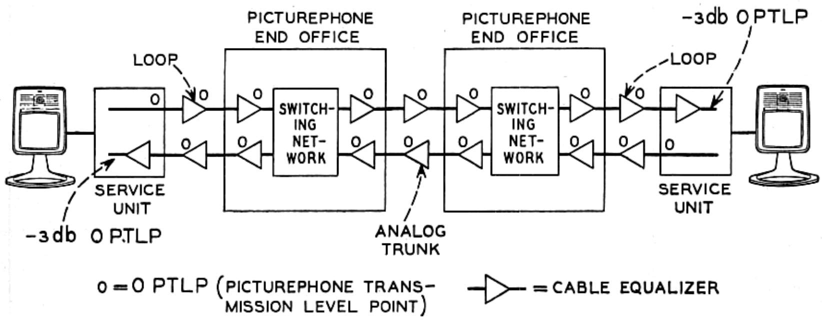

Fig. 4—Overall transmission level plan.

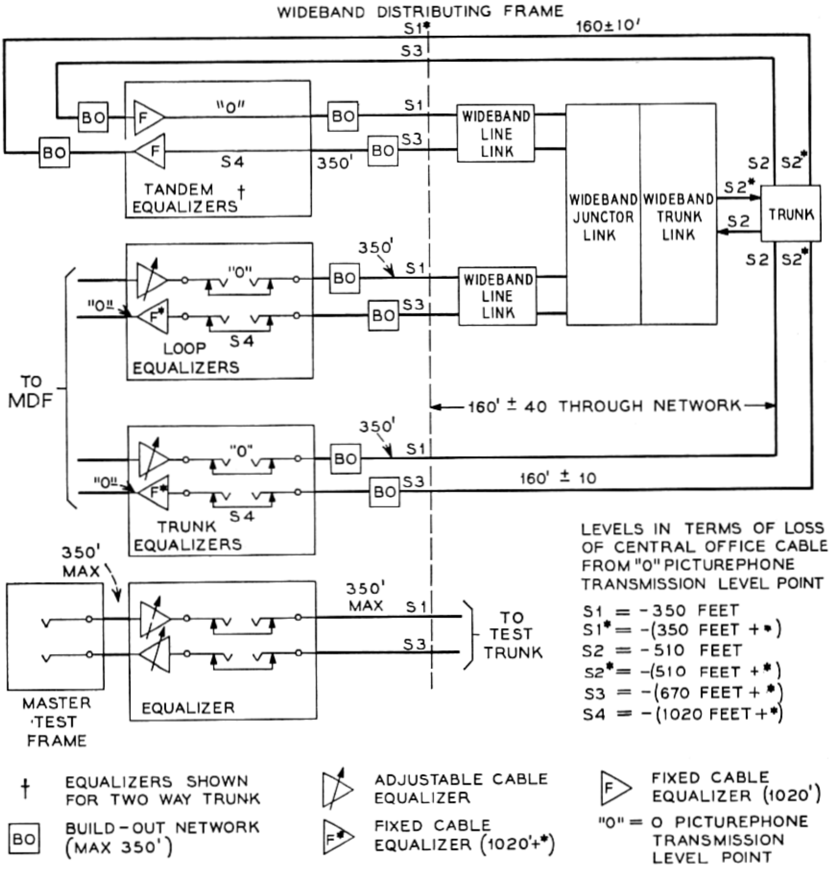

Fig. 5—*Picturephone* switching network level plan.

This total distance was split into two 160-foot sections, one with a ±40-foot variation, and the other with a ±10-foot variation. The level $S2$ at the wideband trunk is $S1$ minus 160 feet of central office cable. The (*) shown in Fig. 5 is used to identify the additional shaped loss contribution by the switching network over that of cable alone. The shaping is equal to the difference between 1020 feet of cable and a nominal path through the wideband switching network. The shaping is primarily contributed by the loss of the multiple cables (bridge taps) on the wideband junctor link. If uncompensated, the shaping would result in video echoes (ghosts) on the *Picturephone* screen. The method used to make these cables as short and uniform as possible is explained in Section 3.2.

Since the network must switch intraoffice and operator calls, the trunks must be at the transmission midpoint, level $S2$, to satisfy the level plan. Figure 5 summarizes the levels in terms of effective loss of central office cable from 0 PTLP.

The wideband line link (WBLL) appearance of two-way and operator trunks passes through the WBDF and a tandem cable equalizer to reestablish 0 PTLP before it enters the wideband network. These appearances terminate directly on the WBDF to take advantage of the traffic assignment flexibility offered.

3.1.2 *Transmission Restrictions Due to Video Impairments*

In addition to the distance restrictions imposed on the central office equipment to satisfy the level plan, a limit on the magnitude of the video impairments—echo, random noise, impulse noise, crosstalk, and power hum—is required to stay within the allowable overall loss allocations.[3] Each of these impairments has a particular effect on the physical design of the wideband network.

For instance, a cable equalizer compensates for some average frequency response and the echo rating impairment of any other path will depend on how it deviates from this average response. Echoes in the switching office, as explained earlier, are caused primarily by the multipling of cables necessary to interconnect the various junctor switch groups. Figure 6 shows echo rating[3] as a function of the number and length of bridge taps. The shaded region of this figure shows the allowable echo rating of the switching office as a function of only unequalized bridge taps, and assumes perfect equalization of both central office cable and switches. Since the allocation of echo is based on an average path, it is necessary to keep the number of bridge taps along the path constant, as short as possible, and at a fixed distance from the cable equalizers.

Noise impairments result from energy in the paths that control relays and crossbar switches being induced into the video pairs, and from wide electrical current fluctuations in the battery and ground feeders coupling through the framework onto the video paths. To stay within the noise allocations, all video cables are separated by at least two inches from control cables when they run parallel to each other on a frame and are run at 90° to each other where the 2″ minimum spacing cannot be maintained. Also, contact protection devices (series RC circuits) are connected between ground and the video switch control leads in order to reduce the effect of high energy transients. Battery and ground feeders for the wideband network are

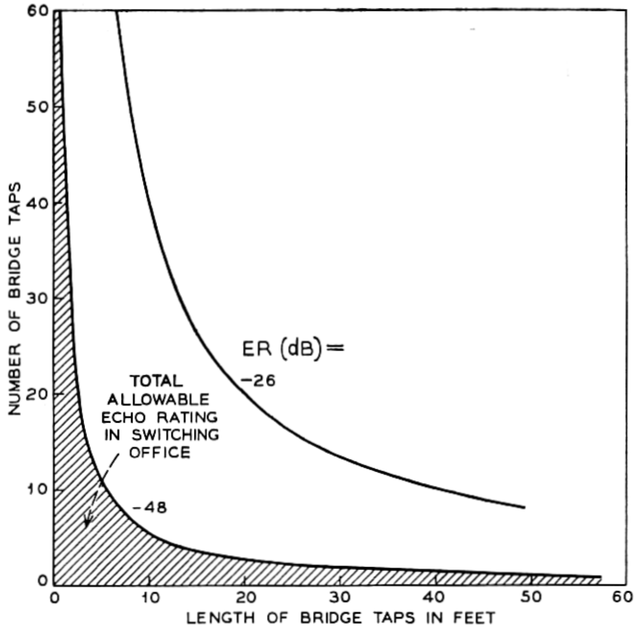

Fig. 6—Echo rating for unequalized bridge taps.

electrically isolated from the audio switching equipment thereby preventing the wide current fluctuations on the audio frames from coupling onto the video frames. Also, all wideband frames in each wideband frame line are interconnected with large copper buses and these buses interconnect at the main aisle to reduce as far as practicable the variation between frame potentials.

Crosstalk is caused by energy in the video transmit pairs coupling into its receive pairs (self crosstalk), or by energy in the transmit and receive pairs of one customer coupling into the transmit and receive pairs of the adjacent customer on the wideband link crossbar switches (worst disturber crosstalk), Fig. 7. While crosstalk cannot be defined exclusively in terms of dB per inch of cable separation, it was found from laboratory measurements that, by applying the following rules to the wideband equipment, the crosstalk allocations can be met.

(*i*) Twisted pair wiring with varying twist lengths must be used for all transmission leads.

(*ii*) The fourth wire on each level of every crossbar switch must be electrically grounded. This *ground plane* tends to electrically isolate the two directions of transmission on the switch.

(*iii*) Transmit and receive leads between switching frames must run in separate cables. This prevents transmission paths of different energy levels from being run adjacent for an appreciable distance.

Power hum impairments are relatively minor in the central office; therefore, the only precautionary step taken is to electrically isolate new appliance outlets from audio frameworks where these outlets are used to supply ac power to video equipment.

3.2 *Physical Design of the Wideband Network*

The wideband network had to satisfy the level plan, stay within the video impairments allotted to it, and grow easily from the 100-trunk termination size to the maximum 400-trunk termination size network. A plan that reserves floor space in the central office for two facing lineups of wideband frames, each approximately 23 feet long, and controls the distance to the surrounding wideband frames satisfied these criteria. This plan with typical frame locations is shown in Fig. 8.

The WBLL frames are designed to have five of the wideband line links shown in Fig. 3 mounted on a basic frame, each with a maximum concentration of 4 : 1. A supplementary line link frame provides for the additional 4 : 1 concentration and is interconnected to its associated basic frame by a short cable connected between the switch horizontals. The WBLL frames grow uniformly in the controlled part of the floor plan as the office requirements for line terminations dictate. The con-

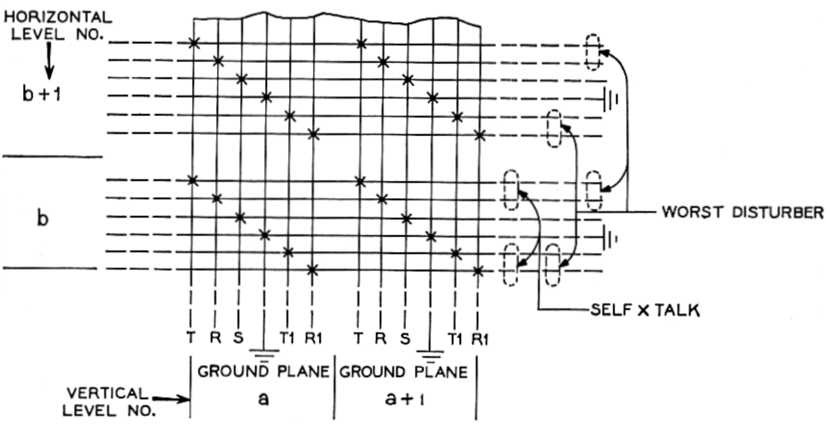

Fig. 7—Wideband crosstalk on crossbar switch.

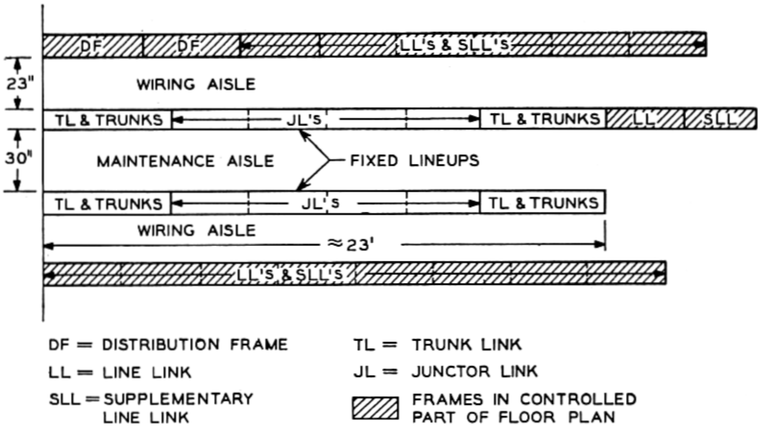

Fig. 8—No. 5 crossbar wideband (WB) switching area typical floor plan.

trol exercised in this part of the floor plan is that a WBLL frame can be placed anywhere in the office, provided the sum of the interframe cabling from the WBDF to a WBLL frame and from this WBLL frame to a wideband junctor link frame (WBJL) is equal to 74 feet. This allows the distance from an office equalizer to a WBJL multiple point (star point) to be constant for any path, except for intraframe wiring variations. The 74-foot cable length dimension provides for reasonable office layout flexibility and is within the limits of the level plan.

The WBJL frames are part of the fixed floor plan. This arrangement allows for the rigid control of: the length and number of bridge taps; the distance from the cable equalizers to a star point; and the transmission path distance through the wideband network. A star point is located on each basic WBJL frame and is used to interconnect the verticals of the junctor switches as the office grows from the 100-output to the 400-output size. In the maximum size office the three interframe multiple cables range from 12 to 18 feet. Cable equalizers are adjusted to compensate for the average loss of these cables. Level variations from the average and not the actual loss of the bridge taps must be within the echo rating allocation for the switching network. As the office grows, capacitors that simulate the loss of these multiple cables are removed. Thus the cable equalizers do not have to be adjusted as the office grows.

The connection of the horizontal multiple between the junctor switch groups is made at the wideband trunk link frame. This ensures that the length of the bridge tap caused by this multiple will have little variation regardless of the path chosen. A more direct connection of this bridge tap could have been made; however, the cable equalizers could not in this case compensate for the variation in loss among the paths.

The wideband trunk link (WBTL) frames are the other frames in the fixed floor plan. The interframe cable distances between the WBJL frames and the WBTL frames are fixed so that compensation for the bridge taps can be accomplished and the length restrictions imposed by the level plan can be satisfied. The WBTL and wideband trunks are mounted on the same double bay frame. The trunk link switches are mounted in one bay and the wideband trunks in the other. Connection between the horizontals of the WBTL switches and the trunks is made through an intraframe cable that terminates on a terminal strip in the middle of the WB trunk bay. This also provides flexibility for the addition of new features. The trunks can be assigned to switch horizontals by loose wire cross-connections made on the front of the bay. This technique of cabling reduces path length variation and is the final step in satisfying the level plan.

By applying the rules listed in Section 3.1.2 and by utilizing the fixed and controlled floor plan, both the video impairment allocations for the central office and the level plan are satisfied.

3.3 *Wideband Network Simulation*

A hardware simulation of the overall switching network was developed to determine the realizability of the plan; the simulation was not intended to characterize a typical *Picturephone* switching office. The simulated network was arranged so that initially it represented a best case wideband network from a transmission standpoint without concern for optimizing the cost or flexibility. The network was then modified in steps to minimize cost and maximize physical flexibility.

The test plan for the simulation was to determine if the best case network would satisfy the transmission requirements; if it could not, then testing would stop and a reevaluation of the overall transmission plan would be made. The best case network was satisfactory and the simulated network was modified to incorporate the standard manufacturing and installation techniques that allow the network to be physically practical.

Virtually every modification of the simulation network uncovered a different transmission degradation that was close to the switching office allocation. As the tests progressed, design changes were made to lower these degradations until the cost trade-offs dictated that no further improvements could be made. As a result, the standard service designs represent a balance of satisfactory transmission with reasonable cost and physical flexibility.

IV. CALL PROCESSING

4.1 *Control Elements*

As indicated earlier, the designs for *Picturephone* service use as much of the telephone plant as possible. This is particularly true with the call processing elements in the No. 5 crossbar system. Nonetheless, additional control functions and circuitry are needed. The following paragraphs describe some of these additional controls.

The network control for the WBL is provided by additional circuitry in completing markers 0 and 1. Only one completing marker out of the possible 12 is needed to handle the expected *Picturephone* traffic; for reliability, a second is modified for *Picturephone* service. The markers gain access to the WBL through new connectors. In order to establish the association between line appearances on the audio and video networks, a wideband line control circuit is provided. This circuit translates the audio line equipment location into a corresponding video line equipment location and provides access by the marker to the corresponding video appearance on the WBL. Wideband trunk circuits provide access by the marker to the video transmission paths and control the state of the video paths based on signals from the associated audio trunk.

In order to transmit and receive control signals to and from the WBRS, a wideband remote switch signal control (WBRSSC) circuit is provided. To conserve cable pairs between the central offce and WBRS, the WBRSSC circuit encodes much of the information it receives. The signals transmitted from the central office are received by sensitive mercury contact relays and decoded to operate control relays and the select and hold magnets of the crossbar switches. The dc signals are passed over approximately 30 pairs of wires. (While a data link was considered as a way of transmitting these signals, it did not prove economical because of the short distances involved—centrex CO customers are rarely more than a few miles from the central office—and the relatively small number of signals required.)

4.2 *Special Signals for* Picturephone *Call Processing*[1]

4.2.1 *Video Supervisory Signal*

Since a *Picturephone* station can originate and receive both telephone and *Picturephone* calls, it is unnecessary (and wasteful of power) to turn the set on every time the station is used. Hence, it would be useful to enable the set on *Picturephone* calls only. Also, it is desirable to trigger the set to give a distinctive ring on incoming *Picturephone* calls. To provide both of these features, a special signal is sent to both calling and called *Picturephone* sets when a *Picturephone* call is being established. The signal, called the video supervisory signal (VSS)[1], consists of the standard horizontal and vertical sync pulses of the video signal format with a constant "gray level" voltage between these pulses. VSS is coupled from a new signal source to the outgoing video pair via the wideband trunk circuits. The new VSS supply source uses the timing and logic integrated circuit substrate originally designed for the *Picturephone* set.

4.2.2 *Video Continuity Signal*

Because charging and supervision for *Picturephone* calls is controlled on the audio path, a test is required on every call to assure the integrity of the video path. To provide this assurance, a video continuity test is made while the marker is processing the call. The test is accomplished by using a 12-kHz sine wave generator and detector per marker and by employing "loop-backs"—switched connections between the video transmit pair and receive pair—at the interoffice wideband trunk circuits and at the *Picturephone* station set. The marker makes the test by applying a tone through the wideband trunk circuit onto the outgoing video pair. The signal is looped back at the distant point (the next trunk or the station set) and is returned on the incoming video pair where it is detected by the marker and checked to determine its amplitude level. The signal level must fall within a specified "window"—8.2 dB wide when checking to the station, 2.6 dB wide when checking to a distant trunk—before proceeding with call setup. Section 4.3 presents a more detailed discussion of how this signal is used.

The chosen frequency and level detection scheme does provide a reasonable check for those problems and equalizer misadjustments that are expected to be encountered most frequently. It could reasonably be argued that a single frequency signal does not provide a thorough check of the entire megahertz bandwidth. However, other signals such as those which are higher in frequency or which have wide bandwidths are too expensive to generate and detect relative to their usefulness for facility checking.

4.3 *Interaction of Controls and Signals*

As a way of describing how the various control elements and signals interact, a typical call is described that originates from a customer associated with a WBRS and terminates in a distant office.

When the customer at the *Picturephone* station originates a call by going off-hook, a dial tone marker in the No. 5 office connects the audio pair of the station set to a *Touch-Tone* originating register in the usual manner. When the register returns dial tone to the customer, the customer keys the desired number, prefixed with the "#" button if he intends the call to be a *Picturephone* call or without the prefix if the call is a standard telephone call. If the "#" is not keyed, the register bids for a completing marker and the call is handled in the usual fashion. If the prefix is keyed, the register bids only for completing markers 0 and 1, the only markers arranged to complete *Picturephone* calls. (The other markers are made to appear busy to this register on this call.) The register passes the keyed number, a signal to indicate that the "#" was keyed, and other information about the calling line to the marker. With this information, the marker interrogates the wideband line control circuit to determine whether the customer requesting a *Picturephone* call is in fact entitled to *Picturephone* service and whether the video appearance of the line is terminated at the central office or at the remote switch.

Using the called number, the marker tests the busy-idle status of *Picturephone* trunks to the desired destination and then chooses one of the idle trunks. Since this call is from a station with a WBRS appearance, the marker must also select an idle video link between the remote location and central office. This selection process is performed through the WBRSSC circuit via the wideband network connectors. Once the trunk is selected, the marker looks for idle channels through both the audio and video networks.

While in the process of selecting idle channels, the marker performs a continuity test over the trunk video transmission facilities. If the test is unsuccessful, a marker makes a second trial to set the call to a different trunk and then (if again unsuccessful) returns reorder tone over the audio facilities to the calling customer. If the test is successful, all crosspoints of the selected audio and video channels through the networks are closed except for the crosspoints of the WBRS and the audio and video line link stages. (While the end points of the network are logically associated as discussed in Section

2.1, it should be noted that the channels through each network are chosen independently and concurrently. Hence, the WBL is not a slaved network.)

When the crosspoints have closed, the marker applies a "false cross and ground" (FCG) check on both the audio and video channels. The audio test is the same as that now used in regular telephone service. The new video test checks that, within the network, none of the following conditions exists:

(*i*) A false dc ground on any one of the four transmission leads.
(*ii*) A false dc signal path between the transmit and receive portions of the channel being set up.
(*iii*) A false dc signal path between the channel being set up and a channel in use.

Upon completion of the FCG test, the marker operates the remaining crosspoints and applies a continuity test toward the 0-dB loopback at the station set. A failure at this point will result in a reorder tone being applied from the audio trunk to the calling customer.

With a successful test, the marker signals the outgoing trunk to apply a 100-millisecond burst of VSS toward the calling set and then releases from this call. (The VSS signal is applied only as a burst since it is comtemplated that future wideband intercept announcements, which inform the calling customer of some problem in setting the call, may include a video scene as well. Hence, the video scene would not be viewed by the calling customer if VSS were applied continuously.) The usual address and supervisory information is passed over the audio trunk to the next office.

At the terminating office, similar actions occur, but with a few differences. For example, the continuity check is made only to the subscriber since the incoming trunk has already been checked by the preceding office. In addition, VSS is applied continuously toward the called station, starting at least 100 milliseconds before ringing begins. The combination of VSS and the ringing signal causes the station set to give a distinctive ring and triggers the set into a state that will turn it on when the customer answers. The video path is cut through when the called party answers, and charging for the call begins.

V. ADDITIONAL FEATURES

5.1 *Operator Services*

Operator assistance is provided for the *Picturephone* customers on special calls such as person-to-person, collect, and credit card calls. This assistance is provided by operators working at switchboards, called

3CL boards. Trunk circuits connect the No. 5 *Picturephone* office and the 3CL boards to provide the operator assistance. While the central office still switches a parallel audio and video path to these trunks for eventual cut-through to the calling and called *Picturephone* customers, only the audio signals are passed between the central office trunk and the 3CL board. This arrangement allows the operator to be located remotely from the central office without requiring *Picturephone* transmission facilities to the operator.

The operator can assist in two types of calls. The first, a dial zero call, is one in which the customer calls the operator by keying "# + 0" and the operator extends this call to the called customer. A dial zero trunk from the No. 5 office is used for this type of traffic. The second type, a delayed call, is one in which the operator calls both the calling and called customers. The operator uses a delayed call trunk from the No. 5 office.

The primary difference between a customer controlled call and an operator controlled call is video cut-through. In particular, when a customer dials his own toll call, the video path is cut-through when the called party answers. On operator calls, however, the video path is kept under key control by the operator.

5.2 *Maintenance Features*

In addition to the extensive testing arrangements already provided in the maintenance center of No. 5 crossbar, a number of unique arrangements have been provided for additional maintenance capability for *Picturephone* service.[4] A discussion of some of them follows.

5.2.1 *Video Make-Busy*

With the additional complexity of the video transmission facilities, a feature that prevents a *Picturephone* customer from originating or receiving *Picturephone* calls but allows him to have telephone communications is a useful maintenance tool. This feature, a video make-busy capability, is implemented with magnetically latching relays provided on a one per *Picturephone* line basis. With the relay operated, only telephone calls and *Picturephone* test calls can be connected to the line. The state of the relay can be changed by the 15A local test desk[5] or by the master test control (MTC) circuit in the switching maintenance center.

5.2.2 *WBRS Test Arrangements*

If a craftsman is working with a WBRS as part of a trouble-tracing procedure or routine testing, he should not have to call a switchman at the central office to set up test calls; he should be able to make the tests himself. To give him this capability, a portable circuit was designed to work into a trunk test register circuit at the central office. With this portable set, the craftsman can set a number of switches and keys that indicate the called number, type of test, various test conditions, etc. The information, in the form of up to 30 digits, is outpulsed to the register using multifrequency (MF) signals. When the information is stored in the register, the register bids for a marker in much the same manner as the MTC circuit. As such, it can simulate a number of controls provided by the MTC.

VI. ACKNOWLEDGMENT

The material described in this paper is the result of the system planning and detailed design efforts of many people in the Local Crossbar Switching Laboratory, the Network Planning Center, and the Switching Engineering Center of Bell Telephone Laboratories.

REFERENCES

1. Urich, J. F., "The *Picturephone®* System: Switching Plan," B.S.T.J., this issue, pp. 521–531.
2. Clos, C., "A Study of Nonblocking Networks," B.S.T.J., *32,* No. 2 (March 1953), pp. 406–424.
3. Brown, H. E., "The *Picturephone®* System: Transmission Plan," B.S.T.J., this issue, pp. 351–394.
4. Dougherty, H. J., Peterson, E. B., and Schachtman, M. G., "The *Picturephone®* System: Maintenance Plan," B.S.T.J., this issue, pp. 621–644.
5. Favin, D. L., and Gilmore, J. F., "The *Picturephone®* System: Line and Trunk Maintenance Arrangements," B.S.T.J., this issue, pp. 645–665.